**Rayat Shikshan Sanstha's**

# Karmaveer Bhaurao Patil College Vashi, Navi Mumbai

## Autonomous College

**[Affiliated to University of Mumbai]**

## Syllabus for MSC-I Mathematics

| Sr. No. | Heading | Particulars |
|---|---|---|
| 1 | Title of Course | M.Sc. I Mathematics (CBCS) |
| 2 | Eligibility for Admission | T.Y.B.Sc. (Mathematics), From a recognized university |
| 3 | Passing Marks | 40% |
| 4 | Ordinances/Regulations (if any) | |
| 5 | No. of Years/Semesters | One year/Two semester |
| 6 | Level | P.G. |
| 7 | Pattern | Semester |
| 8 | Status | New |
| 9 | To be implemented from Academic year | 2023-2024 |

AC-

Item No-

# Rayat Shikshan Sanstha's

## KARMAVEER BHAURAO PATIL COLLEGE, VASHI.

## NAVI MUMBAI

## (AUTONOMOUS COLLEGE)

Sector-15- A, Vashi, Navi Mumbai - 400 703

# Syllabus for M.Sc. I Mathematics

# Program: M.Sc.

# Course: M.Sc. I Mathematics

# (w.e.f. 2023-2024)

## Preamble of the Syllabus:

Master of Science (M.Sc.) in Mathematics is a post-graduation programme of Department of Mathematics, Karmaveer Bhaurao Patil College Vashi, Navi Mumbai [Autonomous College]

The Choice Based Credit System to be implemented through this curriculum, would allow students to develop a strong footing in the fundamentals and specialize in the disciplines of his/her liking and abilities. The students pursuing this course would have to develop understanding of various aspects of the mathematics. The conceptual understanding, development of experimental skills, developing the aptitude for academic and professional skills, acquiring basic concepts and understanding of hyphenated techniques are among such important aspects.

**Rayat Shikshan Sanstha's**

**KARMAVEER BHAURAO PATIL COLLEGE, VASHI, NAVI MUMBAI**

**(Autonomous)**

**Department of Mathematics**

**M. Sc. Mathematics**

## Program Outcomes (POs)

**Learners are able to:**

| | | |
|---|---|---|
| **PO-1** | **Disciplinary Knowledge and Skills** | Acquire the comprehensive and in-depth knowledge of various subjects in sciences such as Physics, Chemistry, Mathematics, Microbiology, Bio-analytical Science, Computer Science, Data Science, Information Technology and disciplinary skills and ability to apply these skills in the field of science, technology and its allied branches. |
| **PO-2** | **Communication and Presentation Skills** | Develop various communication skills including presentation to express ideas evidently to achieve common goals of the organization. |
| **PO-3** | **Creativity and Critical Judgement** | Facilitate solutions to current issues based on investigations, evaluation and justification using evidence-based approach. |
| **PO-4** | **Analytical Reasoning and Problem Solving** | Build critical and analytical attitude in handling the problems and situations. |
| **PO-5** | **Sense of Inquiry** | Curiously raise relevant questions based on highly developed ideas, scientific theories and its applications including research. |
| **PO-6** | **Use of Modern Tools** | Use various digital technologies to explore information/data for business, scientific research and related purposes. |

| | | |
|---|---|---|
| **PO-7** | **Research Skills** | Construct, collect, investigates, evaluate and interpret information/data relevant to science and technology to adapt, evolve and shape the future. |
| **PO-8** | **Application of Knowledge** | Develop scientific outlook to create consciousness against the social myths and blind faith. |
| **PO-9** | **Moral and Ethical Reasoning** | Imbibe ethical, moral and social values to develop virtues such as justice, generosity and charity as beneficial to individuals and society at large. |
| **PO-10** | **Leadership and Teamwork** | Work cooperatively and lead proactively to achieve the goals of the organization by implementing the plans and projects in various field-based situations related to science, technology and society at large. |
| **PO-11** | **Environment and Sustainability** | Create social awareness about environment and develop sustainability for betterment of future. |
| **PO-12** | **Lifelong Learning** | Realize that pursuit of knowledge is a lifelong activity and in combination with determined efforts, positive attitude and other qualities to lead a successful life. |

| **Program Specific Outcomes (PSO)** | |
|---|---|
| | |
| **PSO1** | Recalling the concepts of mathematics and applying them to the various courses like algebra, analysis, Differential equations, statistics, etc to form mathematical models. |
| **PSO2** | Apply Mathematics to interdisciplinary ways like statistician, mathematical finance, industry expertise and interpret quantitative ideas. |
| **PSO3** | Apply knowledge of Mathematics for research and engineering. |

Rayat Shikshan Sanstha's

# KARMAVEER BHAURAO PATIL COLLEGE, VASHI

[AUTONOMOUS COLLEGE]

## Department of Mathematics

### M.Sc. Mathematics

## Teaching - Evaluation Scheme (NEP 2020)

### Semester-I

| Course Code | Course Name | Teaching Scheme (Hours/Week) | | | Examination Scheme and Marks | | | | | | Credit Scheme | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Lecture | Practical | Tutorial | CIE | Sem End-Exam | Term | Practical | Oral | Total | Lecture | Practical | Tutorial | Total |
| MAT401 | Algebra-I | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| MAT402 | Analysis-I | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| MAT403 | Complex Analysis and | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 06 |
| | Discrete Mathematics | 02 | | | 20 | 30 | | | | 50 | 02 | | | |
| MAT404A Or MAT404B | Introduction to R Programming-I Or Advanced Python-I | 02 | 02 | - | - | 60 | - | 40 | - | 100 | 02 | 02 | - | 04 |
| MAT405 | Research Methodology | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| | **Total** | **20** | **02** | **-** | **180** | **230** | **-** | **40** | - | **550** | **20** | **02** | **-** | **22** |
| | | | | | | | | | | **Total Credit** | **20** | **02** | **-** | **22** |

### Semester-II

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAT451 | Algebra-II | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| MAT452 | Topology | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| MAT453 | Differential Equation and | 04 | - | - | 40 | 60 | - | - | - | 100 | 04 | - | - | 06 |
| | Integral Transform | 02 | | | 20 | 30 | | | | 50 | 02 | | | |
| P MAT454A Or MAT454B | Introduction to R Programming-II Or Advanced Python-II | 02 | 02 | - | - | 60 | - | 40 | - | 100 | 02 | 02 | - | 04 |
| MAT455 | Internship | 04 | - | - | 60 | 60 | - | - | - | 100 | 04 | - | - | 04 |
| | **Total** | **20** | **02** | **-** | **180** | **230** | | **40** | - | **550** | **20** | **02** | **-** | **22** |
| | | | | | | | | | | **Total Credit** | **21** | **01** | **-** | **22** |

**COURSE STRUCTURE FOR M.Sc. I MATHEMATICS**

## SEMESTER I

| | Course | Unit | Topic | Credit | L/W |
|---|---|---|---|---|---|
| **Major** | **Algebra I** | | | | |
| | MAT401 | I | Dual spaces | 4 | 4 |
| | | II | Homogeneous Linear Differential Equations with Constant Coefficients and Determinants | | |
| | | III | Invariant Subspaces | | |
| | | IV | Bilinear forms | | |
| **Major** | **Analysis I** | | | | |
| | MAT402 | I | Euclidean space $\mathbb{R}^n$ | 4 | 4 |
| | | II | Riemann integration | | |
| | | III | Differentiable functions | | |
| | | IV | Inverse function theorem, Implicit | | |
| **Major** | **Complex Analysis and Discrete Mathematics** | | | | |
| | MAT403 | I | Holomorphic functions | 6 | 6 |
| | | II | Contour integration, Cauchy-Goursat | | |
| | | III | Holomorphic functions and their properties | | |
| | | IV | Singularities, Conformal Mappings, and multivalued Functions | | |
| | | V | Number Theory | | |
| | | VI | Advanced Counting | | |
| **Elective** | **Introduction to R Programming-I** | | | | |
| | MAT404A | I | Introduction to R | 4 | 4 |
| | | II | R Function | | |
| | | III | Data Frames | | |
| | | IV | Practical | | |
| | MAT404B | **Advanced Python-I (ref. Syllabus from CS Dept)** | | 4 | 4 |
| **RM** | **Research Methodology** | | | | |
| | MAT405 | I | Fundamentals of Research Methodology | 4 | 4 |
| | | II | Data Collection | | |
| | | III | Data Analysis and Reporting | | |
| | | IV | Intellectual Property Rights | | |

## SEMESTER II

| | Course Code | Unit | Topic | Credit | L/W |
|---|---|---|---|---|---|
| **Major** | **Algebra II** | | | | |
| | MAT451 | I | Groups, group homomorphisms | 4 | 4 |
| | | II | Groups acting on sets and Sylow's theorems | | |
| | | III | Rings, Fields | | |
| | | IV | Divisibility in integral domains, finite fields | | |
| **Major** | **Topology** | | | | |
| | MAT452 | I | Topological spaces | 4 | 4 |
| | | II | Connected and Compact topological | | |
| | | III | Countability and Separation Axioms | | |
| | | IV | Complete metric spaces | | |
| **Major** | **Differential Equations and Integral Transform** | | | | |
| | MAT453 | I | Picard's theorem | 6 | 6 |
| | | II | Linear Ordinary Differential Equations | | |
| | | III | Series solutions and Sturm Liouville's theory | | |
| | | IV | Fourier series | | |
| | | V | Laplace Transform | | |
| | | VI | Fourier Transform | | |
| **ELECTIVE** | **Introduction to R Programming-II** | | | | |
| | MAT454A | I | Loading and handling Data in R | 4 | 4 |
| | | II | Descriptive Statistic | | |
| | | III | Machine Learning | | |
| | | IV | Practical-I | | |
| | **Advanced Python-II** | | | | |
| | MAT454B | **Advanced Python-II (Ref. Syllabus from CS Department)** | | 4 | 4 |
| **Internship** | | **Internship** | | 4 | 4 |

**Note: 1.** Blue Highlighted Topic / Course has focused on employability/ entrepreneurship/skill development

2. Yellow Highlighted Topic / Course is related to professional ethics, gender, human values, Environment & sustainability

3. Green Highlighted Topic / Course is related to local/national/regional & global development needs.

**SEMESTER I**

## MAT401: ALGEBRA I

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

(All Results have to be done with proof unless otherwise stated).

### Unit I. Dual spaces (15 Lectures)

(Review) Vector spaces over a field, linear independence, basis and dimension, infinite dimensional vector spaces. Linear transformations, kernel and image, relationship of linear transformations with matrices, invertible linear transformations, rank-nullity theorem (for finite dimensional vector spaces), application: characterization of an isomorphism from a finite-dimensional vector space to itself. (No question be asked)

Dual spaces of a vector space, dual basis (for finite dimensional vector spaces), Double dual $V^{**}$ of a Vector space V and canonical embedding of V into $V^{**}$. Isomorphism of V and its double dual in the finite-dimensional case. Transpose $T^t$ of a linear transformation T, relation between matrices representing T and $T^t$.

### Unit II. Determinants, Eigen values and Eigenvectors (15 Lectures)

Determinants as an alternating multilinear map, existence and uniqueness, Laplace expansion of determinant, determinants of products and transposes, determinants and invertible linear transformations, determinant of a linear transformation.

Eigen values and Eigen vectors, Characteristic polynomial, Minimal polynomial, Triangulable and diagonalizable linear operators. Matrix limits and Markov chains. Application of Stochastic Matrices: Google Page Rank Algorithm

### Unit III. Invariant Subspaces and Applications (15 Lectures)

Invariant subspaces and Cayley-Hamilton theorem. Nilpotent linear transformations on finite dimensional vector spaces, computations of Minimum polynomials and Jordan Canonical Forms for nilpotent matrices, Jordan canonical forms in general through examples.

The derivative operator on $\mathbb{C}^\infty$, the space of infinitely differentiable functions, polynomial operators, solution space as a subspace of $\mathbb{C}^\infty$, Solution to an equation of order 1, the general case and connection with the auxiliary polynomial.

Application of Jordan Canonical Form in solving system of linear differentiable equations.

**Unit IV: Bilinear forms (15 Lectures)**

(Review) Inner product spaces, orthonormal basis. (No question be asked)
Adjoint of a linear operator, normal and self-adjoint operators, unitary operators and orthogonal operators and their matrices, orthogonal projections and the spectral theorem.
Applications: Singular Value Decomposition. Bilinear and quadratic forms, Sylvester's Law.
Least squares method as an application of orthogonal projection. Application of SVD to least square solutions and Image Compression.

**Recommended Text Books:**


1. S.H.Friedberg, A. J. Insel, L.E.Spence: Linear Algebra, 4th Ed. Prentice-Hall.
2. S. Kumaresan: Linear Algebra, a Geometric Approach, Prentice-Hall.
3. David Lay: Linear Algebra and Applications.
4. Gilbert Strang: Introduction to Linear Algebra, Wellesley-Cambridge Pres.
5. Steven G. Krantz: Jordan Canonical Form Theory and Practice.
6. Serge Lang: Linear Algebra, Springer-Verlag Undergraduate Text in Mathematics.


## MAT401 - Algebra I

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative
(Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://onlinecourses.nptel.ac.in/noc20_ma34/preview
2. https://onlinecourses.nptel.ac.in/noc19_ma23/preview
3. https://onlinecourses.nptel.ac.in/noc21_ma50/preview

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | - | - | 1 | - | - | - | - | - | - | - | 1 |
| CO2 | 1 | 1 | - | 1 | - | - | - | - | - | - | - | 1 |
| CO3 | 2 | 1 | - | 1 | - | - | - | - | - | - | - | 1 |
| CO4 | 3 | - | - | 2 | - | - | - | - | - | - | - | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO5** | 1 | - | - | 2 | - | - | - | - | - | - | - | 1 |

***In CO-PO Mapping Matrix:** a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

## MAT402: ANALYSIS I

**Course Outcome of Analysis I:**

**Students will be able to:**

1. Recall Inner product space, norm linear space and vector space.
2. Distinguish among open and closed sets on different topologies of $\mathbb{R}^n$.
3. Determine whether a function is Riemann integrable using definition and Riemann criteria.
4. List the results on total derivative.
5. Compare Taylor's theorem for one and more variables.
6. Apply second derivative to find maxima and minima of a differentiable functions.

### Unit I. Euclidean space $\mathbb{R}^n$ (15 Lectures)

Euclidean space $\mathbb{R}^n$ : inner product $\langle x, y\rangle = \sum_{j=1}^{n}$ xjyj of $x = (x_1, x_2, \dots \dots x_n) \quad y = (y_1, y_2, \dots \dots y_n) \in \mathbb{R}^n$ and properties, norm $\|x\| = \sqrt{\sum_{j=1}^{n} x_j^2}$ of $x = (x_1, x_2, \dots \dots x_n) \quad \in \mathbb{R}^n$ , Cauchy-Schwarz inequality, properties of the norm function $\|x\|\ of\ \mathbb{R}^n$ (ref: [4] W. Rudin or [5] M. Spivak)

Standard topology on $\mathbb{R}^n$: open subsets of $\mathbb{R}^n$, closed subsets of $\mathbb{R}^n$, interior $A^0$ and boundary $\partial A$ of a subset A of $\mathbb{R}^n$: (ref: [5] M. Spivak)

Operator norm $\|T\|$of a linear transformation T : $\mathbb{R}^n \to \mathbb{R}^m$ ($\|T\| = \sup\{\|T(v)\|: v \in \mathbb{R}^n \ \&\ \|v\| \leq 1\}$)
and its properties such as: For all linear maps S, T : $\mathbb{R}^n \to \mathbb{R}^m$ and R : $\mathbb{R}^m \to \mathbb{R}^k$

1. $\|S + T\| \leq \|S\| + \|T\|$
2. $\|RoS\| \leq \|R\|\|S\|$
3. $\|cT\| = |c|\|T\|, c \in \mathbb{R}$

(Ref: [1] C.C. Pugh or [2] A. Browder)
Compactness: Open cover of a subset of $\mathbb{R}^n$, Compact subsets of $\mathbb{R}^n$ (A subset K of $\mathbb{R}^n$ is compact if every open cover of K contains a finite subcover), Heine-Borel theorem (statement only), the Cartesian product of two compact subsets of $\mathbb{R}^n$ is compact (statement only), every closed and bounded subset of $\mathbb{R}^n$ is compact. Bolzano-Weierstrass theorem: Any bounded sequence in $\mathbb{R}^n$ has a converging subsequence.

Brief review of following three topics:

1. Functions and Continuity: Notation: A $\subset \mathbb{R}^n$ arbitrary non-empty set. A function $f: A \to \mathbb{R}^m$ and its component functions, continuity of a function ( $\in -\delta$; definition). A function $f: A \to \mathbb{R}^m$ is continuous if and only if for every open subset V$\subset \mathbb{R}^m$there is an open subset U of $\mathbb{R}^n$ such that $f^{-1}(V) = A \cap U$.
2. Continuity and compactness: Let K$\subset \mathbb{R}^n$ be a compact subset and f: K$\to \mathbb{R}^m$ be any continuous function. Then f is uniformly continuous, and f(K) is a compact subset of $\mathbb{R}^m$
3. Continuity and connectedness: Connected subsets of are intervals. If f:E$\to \mathbb{R}$ is continuous where E$\subset$ $R^n$ and E is connected , then f(E) $\subset \mathbb{R}$ is connected.

**Unit II: Riemann Integration (15 Lectures)**

Riemann Integration over a rectangle in $\mathbb{R}^n$ ; Riemann Integrable functions, Continuous functions are Riemann integrable, Measure zero sets, Lebesgues Theorem (statement only), Fubini's Theorem and applications.
Reference for Unit II: M. Spivak, Calculus on Manifolds.

**Unit III: Differentiable functions (15 Lectures)**

Differentiable functions on $\mathbb{R}^n$, the total derivative $(Df)_p$ of a differentiable function f : U$\to \mathbb{R}^m$ at p $\in$ U where U is open in$\mathbb{R}^n$; uniqueness of total derivative, differentiability implies continuity. (ref: [1] C.C. Pugh or [2] A. Browder)

Chain rule, Applications of chain rule such as:

1. Let $\gamma$ be a differentiable curve in an open subset U of $\mathbb{R}^n$: Let f : U U$\to \mathbb{R}$ be a differentiable function and let g(t) = f($\gamma$ (t)). Then g′(t) = $\langle(\nabla f(\gamma(t), \gamma'(t)\rangle$.
2. Computation of total derivatives of real valued functions such as
   (a) the determinant function det(X), X $\in M_n(\mathbb{R})$.
   (b) the Euclidean inner product function $\langle x, y\rangle$, (x, y) $\in \mathbb{R}^n \times \mathbb{R}^n$

(ref: [5] M. Spivak & [4] W. Rudin)

Results on total derivative:

1. If f : $\mathbb{R}^n \to \mathbb{R}^m$is a constant function, then $(Df)_p = 0 \ \forall\ p \in \mathbb{R}^n$
2. If f : $\mathbb{R}^n \to \mathbb{R}^m$ is a linear map, then $(Df)_p$ = f $\forall\ p \in \mathbb{R}^n$
3. A function f = ($f_1$,$f_2$,…, $f_m$): $\mathbb{R}^n \to \mathbb{R}^m$ is differentiable at p $\in \mathbb{R}^n$ if and only if each $f_j$ is differentiable at p $\in \mathbb{R}^n$; and $(Df)_p$ = (($Df_1$)$_p$ ,($Df_2$)$_p$,…, ($Df_m$)$_p$).

(ref: [5] M. Spivak)

Partial derivatives, directional derivative $(D_u f)(p)$ of a function f at p in the direction of the unit vector, Jacobian matrix, Jacobian determinant. Results:

1. If the total derivative of a map f = ($f_1$, … , $f_m$) : U$\to$ $\mathbb{R}^m$ (U open subset of $\mathbb{R}^n$) exists at p $\in$ U; then all the partial derivatives $\frac{\partial f_j}{\partial x_j}$ exist at p
2. If all the partial derivatives $\frac{\partial f_j}{\partial x_j}$ of a map f = ($f_1$, $f_2$,…, $f_m$) : U$\to$ $\mathbb{R}^m$ (U open subset of $\mathbb{R}^n$) exist and are continuous on U, then f is differentiable. (ref:[4] W. Rudin)

Derivatives of higher order, C $^k$-functions, $C^\infty$-functions. (ref: [3] T. Apostol)

**Unit IV: Inverse function theorem, Implicit function theorem (15 Lectures)**

Theorem (Mean Value Inequality): Suppose f : U$\to$ $\mathbb{R}^m$ is differentiable on an open subset U of $\mathbb{R}^n$and there is a real number such that $\|(Df)_x\| \leq M \ \forall\ x \in$ U. If the segment [p, q] is

contained in U; then $\|f(q) - f(p)\| \leq M\|q - p\|$ (ref: [1] C.C. Pugh or [2] A. Browder)
Mean Value Theorem: Let f : U→ $\mathbb{R}^m$ is differentiable on an open subset U of $\mathbb{R}^n$. Let p, q ∈ U such that the segment [p; q] is contained in U. Then for every vector $v \in \mathbb{R}^n$ there is a point $x \in$ [p, q] such that $\langle v, f(q) - f(p)\rangle = \langle v, (Df)_x(q - p))\rangle$. (ref: [3] T. Apostol)
If $f : U \to \mathbb{R}^m$ is differentiable on a connected open subset U of $\mathbb{R}^n$ and $(Df)_x = 0 \; \forall$ x ∈ U, then f is a constant map.
Taylor expansion for a real valued $C^m$-function defined on an open subset of $\mathbb{R}^n$, stationary points (critical points), maxima, minima, saddle points, second derivative test for extrema at a stationary point of a real valued $C^2$-function defined on an open subset of $\mathbb{R}^n$. (ref: [3] T. Apostol)

Contraction mapping theorem. Inverse function theorem , Implicit function theorem. (ref: [2] A. Browder)

**Recommended Text Books**


1. C.C. Pugh: Real mathematical analysis, Springer UTM.
2. A. Browder: Mathematical Analysis, An Introduction, Springer.
3. T. Apostol: Mathematical Analysis, Narosa.
4. W. Rudin: Principles of Mathematical Analysis, Mcgraw-Hill India.
5. M. Spivak: Calculus on Manifolds, Harper-Collins Publishers.


## MAT402- Analysis I

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative
(Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1) Basic Calculus-1 - Course https://onlinecourses.nptel.ac.in/noc20_ma34/preview
2) Basic real analysis - Course https://onlinecourses.nptel.ac.in/noc19_ma23/preview
3) Multivariable calculus - Course https://onlinecourses.nptel.ac.in/noc21_ma50/preview

## The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | | - | - | - | - | - | - | - | 1 |
| CO2 | - | - | 2 | 1 | - | - | - | - | - | - | - | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO3** | - | - | 1 | 2 | - | - | - | - | - | - | - | 1 |
| **CO4** | 1 | - | - | 2 | 1 | - | - | - | - | - | - | 1 |
| **CO5** | 2 | - | - | 2 | 2 | - | - | - | - | - | - | 1 |

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

## MAT403: COMPLEX ANALYSIS AND DISCRETE MATHEMATICS

**Course Outcome of Complex Analysis and Discrete Mathematics**

**Students will be able to:**

1. Represent complex numbers algebraically and geometrically.
2. Define and analyse limits and continuity for complex functions as well as consequences of continuity.
3. Apply the Cauchy-Riemann equations and results on harmonic and entire functions including the fundamental theorem of algebra.
4. Analyse sequences and series of analytic functions and types of convergence.
5. Evaluate complex contour integrals directly and by the fundamental theorem, apply the Cauchy integral theorem in its various versions.
6. Represent functions as Taylor, power and Laurent series, classify singularities and poles, find residues and evaluate complex integrals using the residue theorem.

**Unit I: Holomorphic functions (15 Lectures)**

Review: Complex Numbers, Geometry of the complex plane, Riemann sphere, Complex sequences and series, Sequences and series of functions in $\mathbb{C}$ , Weierstrass's M-test, Uniform convergence, (no questions be asked).

Complex differentiable functions, Cauchy-Riemann equations, A complex differentiable function defined on an open subset of $\mathbb{C}$ is called a Holomorphic function.

Ratio test and root test for convergence of a series of complex numbers. Complex Power series, radius of convergence of a power series, Cauchy-Hadamard formula for radius of convergence of a power series. Examples of convergent power series such as exponential series, cosine series and sine series, and the basic properties of the functions $e^z$, cos z, sin z.

Abel's theorem: Let $\sum_{n\geq 0} a_n(z-z_0)^n$ be a power series, of radius of convergence R > 0. Then the function f defined by f(z) =$\sum \quad a_n(z-z_0)^n$ is holomorphic on the open ball $|z-z_0| < R$ and $f'(z) = \sum_{n\geq 1} n a_n(z-z_0)^{n-1}$ $\forall |z-z_0| < R$.

Applications of Abel's theorem such as $exp'(z) = exp\, z$, $cos'(z) = -sin\, z, sin'(z) = cos\, z$ ($z \in \mathbb{C}$)

Chain Rule. A basic result: Let $\Omega_1, \Omega_2$ be open subsets of $\mathbb{C}$. Suppose $f : \Omega_1 \to \mathbb{C}$ is a Holomorphic function with $f'(z) \neq 0\ \forall\ z \in \Omega_1$ and $g : \Omega_2 \to \mathbb{C}$ be a continuous function such that $g(\Omega_2) \subset \Omega_1$ and $f\big(g(w)\big) = w\ \forall\ w \in \Omega_2$. Then g is a holomorphic function on $\Omega_2$ and $g'(w) = \frac{1}{f'(g(w))}\ \forall\ w \in \Omega_2$.

**Unit II: Contour integration, Cauchy-Goursat theorem (15 Lectures)**

Contour integration, Cauchy-Goursat Theorem for a rectangular region or a triangular region. Primitives. Existence of primitives: If f is Holomorphic on a disc U, then it has a primitive on U and the integral of f along any closed contour in U is 0. Local Cauchy's Formula for discs, Power series representation of Holomorphic functions, Cauchy's estimates, Cauchy's theorem (homotopy version)

**Unit III: Holomorphic functions and their properties (15 Lectures)**

Entire functions, Liouville's theorem, Morera's theorem, the Fundamental theorem of Algebra.

The index (winding number) of a closed curve, Cauchy integral formula. Zeros of Holomorphic functions, Identity theorem. Counting zeros; Open Mapping Theorem, Maximum modulus theorem.

**Unit IV: Isolated singularities, Conformal Mappings and multivalved Functions (15 Lectures)**

Isolated singularities: removable singularities and Removable singularity theorem, poles and essential singularities. Laurent Series development. Casorati-Weierstrass's theorem

Residue Theorem and evaluation of standard types of integrals by the residue calculus method.

Conformal mappings. If $f : G \to \mathbb{C}$ is a holomorphic function on the open subset G of $\mathbb{C}$ and $f'(z) \neq 0\ \forall\ z \in G$. then f is a conformal map. Mobius transformations (fractional linear transformation or linear transformation). Any Mobius transformation which fixes three distinct points is necessarily the identity map. Cross ratio ($z_1, z_2, z_3, z_4$) of four points $z_1, z_2, z_3, z_4$. Cross ratio ($z_1, z_2, z_3, z_4$) is real if and only if the four points $z_1, z_2, z_3, z_4$ lie on a circle.

Multivalved Functions: $\sqrt{Z}$, the logarithm as the inverse of exponential, branches of logarithm, the principal branch ln(z) of the logarithmic function on $\mathbb{C} - \{z \in \mathbb{C}: z \leq 0\}$ is a Holomorphic function and $ln'(z) = \frac{1}{z}$.

**Unit V. Number theory (15 Lectures)**

Divisibility, Linear Diophantine equations, Cardano's Method, Congruences, Quadratic residues, Arithmetic functions,

Types of occupancy problems, distribution of distinguishable and indistinguishable objects into distinguishable and indistinguishable boxes (with condition on distribution) Stirling numbers of second and first kind. Selections with Repetitions.

**Unit VI. Advanced counting (15 Lectures)**

Pigeon-hole principle, generalized pigeon-hole principle and its applications, Erdos- Szekers theorem on monotone subsequences, A theorem of Ramsey. Inclusion-Exclusion Principle and its applications. Derangement. Permutations with Forbidden Positions, Restricted Positions and Rook Polynomials.

**Recommended Text Books:**

1. J. B. Conway, Functions of one Complex variable, Springer.

2. R. Remmert: Theory of complex functions, Springer.
3. A. R. Shastri: An introduction to complex analysis, Macmillan.
4. J. W. Brown and R. V. Churchill : Complex variables and applications
5. L. V. Ahlfors: Complex analysis, McGraw Hill .
6. Donold Sarason: Notes on Complex function theory, Hindustan book agency
7. Steven Krantz: Complex analysis: The geometric view point, second edition, carus mathematical monographs.
8. Introduction to Complex Analysis, Kumarsenan.
9.D. M. Burton, Introduction to Number Theory, McGraw-Hill.
10.Nadkarni and Telang, Introduction to Number Theory

## MAT403 - COMPLEX ANALYSIS AND DISCRETE MATHEMATICS

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative (Experimental, Participative, problem Solving)

**Links: SWAYAM / MOOCS:**

1. NOC:Complex Analysis https://nptel.ac.in/courses/111/106/111106141/
2. Complex Analysis https://nptel.ac.in/courses/111/107/111107056/
3. Advanced Complex Analysis https://nptel.ac.in/courses/111/106/111106084/
4. Mathematics - Discrete Mathematics https://nptel.ac.in/courses/111/107/111107058/
5. Mathematics - Number Theory https://nptel.ac.in/courses/111/103/111103020/

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | 1 | - | | - | - | - | - | - | - | - | 1 |
| CO2 | 1 | - | - | 2 | - | - | - | - | - | - | - | 1 |
| CO3 | 1 | - | 2 | 3 | 1 | - | - | - | - | - | - | 1 |
| CO4 | 2 | - | - | 2 | - | - | - | - | - | - | - | 1 |
| CO5 | 1 | - | 2 | 1 | 1 | - | - | - | - | - | - | 1 |

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

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## MAT404A: INTRODUCTION TO R PROGRAMMING -I

(Theory & Practical: 30 Lectures; Practicals:30 Hrs **)**

**COURSE OBJECTIVES:**

1. Study of fundamentals of R.
2. Use different functions, variables and operators in R
3. Write and execute programming in R by using loop and string
4. Analysed and visualized mathematical statistical functions using R.

**UNIT I. Introduction to R:** What is R? Advantages of R over Other Programming Languages - **R Studio:** R command Prompt, R script file, comments – **Handling Packages in R:** Installing a R Package, Few commands to get started: installed. packages(), packageDescription(), help(), find.package(), library() - Input and Output – Entering Data from keyboard – Printing fewer digits or more digits – Special Values functions : NA, Inf and –inf. **R Data Types:** Vectors, Lists, Matrices, Arrays, Factors, Data Frame. **R-Variables:** Variable assignment, Data types of Variable, Finding Variable ls(), Deleting Variables - **R Operators:** Arithmetic Operators, Relational Operators, Logical Operator, Assignment Operators, Miscellaneous Operators - **R Decision Making:** if statement, if – else statement, if – else if statement, switch statement – **R Loops:** repeat loop, while loop, for loop - Loop control statement: break statement, next statement.

**UNIT II. R-Function:** function definition, Built in functions: mean(), paste(), sum(), min(), max(), seq(), user-defined function, calling a function, calling a function without an argument, calling a function with argument values. **R-Strings** – Manipulating Text in Data: substr(), strsplit(), paste(), grep(), toupper(), tolower(), **R Vectors** – Sequence vector, rep function, vector access, vector names, vector math, vector recycling, vector element sorting - **R List** Creating a List, List Tags and Values, Add/Delete Element to or from a List, Size of List, Merging Lists, Converting List to Vector - **R Matrices** – Accessing Elements of a Matrix, Matrix Computations: Addition, subtraction, Multiplication and Division- **R Arrays:** Naming Columns and Rows, Accessing Array Elements, Manipulating Array Elements, Calculation Across Array Elements - **R Factors** –creating factors, generating factor levels gl().

**UNIT III. Data Frames** –Create Data Frame, Data Frame Access, Understanding Data in Data Frames: dim(), nrow(), ncol(), str(), Summary(), names(), head(), tail(), edit() functions - Extract Data from Data Frame, Expand Data Frame: Add Column, Add Row - Joining columns and rows in a Data frame rbind() and cbind() – Merging Data frames merge() – Melting and Casting data melt(), cast().

**Unit-IV. Practical (Lab Sessions)**

**Recommended Text Books:**

1. Sandip Rakshit, R Programming for Beginners, McGraw Hill Education (India), 2017, ISBN : 978-93-5260-455-5. 2. Seema Acharya, Data Analytics using R, McGrawHill Education (India), 2018, ISBN: 978-93-5260-524-8.
3.Hands-On Programming with R, O'Reilly (Pub.)
4. Andrie de Vries, Joris Meys, R for Dummies A Wiley Brand, 2nd Edition, John Wiley and Sons, Inc, 2015, ISBN: 978-1-119-05580-8.
5. Tutorials Point (I) simply easy learning, Online Tutorial Library (2018), R Programming, Retrieved from https://www.tutorialspoint.com/r/r_tutorial.pdf.
6. https://nptel.ac.in/courses/111/104/111104100/

## MAT404A: INTRODUCTION TO R PROGRAMMING -I

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative
(Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://nptel.ac.in/courses/111/104/111104100/
2. https://nptel.ac.in/courses/111/104/111104120/
3. https://nptel.ac.in/courses/111/104/111104146/

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | 1 | - | 1 | - | - | - | - | - | 1 |
| CO2 | 2 | - | - | 1 | - | 2 | - | - | - | - | - | 1 |
| CO3 | 2 | 1 | 1 | - | - | 1 | - | - | - | - | - | 1 |
| CO4 | 1 | - | - | 2 | - | - | - | 1 | - | - | - | 1 |
| CO5 | 1 | | 1 | | | | | | | | | 1 |

## MAT405: RESEARCH METHODOLOGY

**Course Outcome of Research Methodology:**
**Students will be able to:**

1. Understand fundamental concept of research and define appropriate hypothesis.
2. Collect data and apply different methods for sampling data
3. Analyse data and form report
4. Understand Intellectual Property Rights, patenting and copy right to develop research skill
5. Construct project research report

**Unit –I: Fundamentals of Research Methodology**

**Introduction to Research Methodology:** Meaning and objectives of research, Terminology, Features of a good research study, Ethics in research

**Study designs:** basic, applied, historical, exploratory, experimental, ex-post-facto, case study, diagnostic research, crossover design, case control design, cohort study design, multifactorial design.

**Hypothesis:** Meaning, significance and characteristics of hypothesis, Basic concepts concerning testing of hypotheses, Hypothesis development, Steps in formulation of hypothesis, Statistical hypothesis testing – type 1, type 2 errors, levels of significance

**Unit – II: Data Collection**

**Experimental data collection:** Types of data**,** Methods of primary data collection (observation, experimentation, questionnaire, schedules, interviewing, case, pilot study)**,** Methods of secondary data collection (internal, external)**,** Selection of appropriate method for data collection.

**Sampling:** Terminology, Need for sampling**,** Types of Sampling (probability sampling and non-probability sampling)

**Variable:** Dependent, Independent, Intervening, Moderator, Control variables, Extraneous variables.

**Unit –III: Data Analysis and Reporting**

**Data processing and processing operations:** Problems in processing, Elements of analysis in data processing, Software for data processing e.g. SPSS & SAS

**Scientific writing and publishing:** Report Writing, Writing a Research Paper, Writing a Review Article.

**Unit –IV: Intellectual Property Rights**

**General Regime of Intellectual Property Rights:** Concept of Property vis-à-vis Intellectual Property, Types of Intellectual Property- Origin and Development- An Overview, Intellectual Property Rights as Human Right, Role of International Institutions

**Patent Law** Introduction to Patent Law, Paris Convention, Patent Cooperation Treaty, WTO- TRIPS, Harmonization of CBD and TRIPs

**Indian Patent Law:** Patentable Subject Matter, Patentability Criteria, Procedure for Filing Patent Applications, Patent Granting Procedure, Revocation, Patent Infringement and Remedies Relevant Provisions of the Biological Diversity Act, 2002

**Copyright and Neighbouring Rights:** Introduction to Copyright, Conceptual Basis, International Protection of Copyright and Related rights- An Overview (International Convention/Treaties on Copyright), Indian Copyright Law

**Trademarks** Introduction to Trademarks, Need for Protection of Trademarks Kinds of Trademarks, International Legal Instruments on Trademarks, Indian Trademarks Law

**Text & References:**


1. Research Methodology: C.R. Kothari Second edition
2. http://linguistics.byu.edu/faculty/henrichsenl/ResearchMethods/RM_2_14.html
3. http://linguistics.byu.edu/faculty/henrichsenl/ResearchMethods/RM_2_14.html


## MAT405– RESEARCH METHODOLOGY

**Course Outcomes**: After successful completion of this course, students will be able to:

**CO-1:** Understand fundamental concept of research and define appropriate hypothesis.
**CO-2:** Collect data and apply different methods for sampling data
**CO-3:** Analyse data and form report
**CO-4:** Understand Intellectual Property Rights, patenting and copy right to develop research skill
**CO-5:** Construct project research report

**ICT Tools Used:** Videos, PPT, Sampling Data Analysis

**Students Centric Methods:** Problem Solving and Participative
(Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://nptel.ac.in/courses/121/106/121106007/
2. https://nptel.ac.in/courses/107/108/107108011/
3. https://nptel.ac.in/courses/127/105/127105008/
4. https://nptel.ac.in/courses/110/105/110105139/

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | 2 | - | 1 | 1 | 1 | - | - | - | - | - | 1 |
| CO2 | 2 | - | - | 2 | 1 | 1 | 1 | 1 | - | - | - | 1 |
| CO3 | 2 | 1 | - | - | - | 1 | 1 | - | - | - | - | 1 |
| CO4 | 2 | 2 | - | - | - | - | - | - | - | - | - | 1 |
| CO5 | 2 | 3 | - | - | - | 1 | 1 | - | - | - | - | 1 |

# SEMESTER II

## MAT451: ALGEBRA II

**(**All results have to be done with proof unless otherwise stated.)

**Course Outcome of Algebra-II:**
**Students will be able to:**

1. Understand the concept of group homomorphism, isomorphism and automorphism and apply it for constructing groups.
2. Analyze Class equation, Sylow's theorems and apply them for describing structures of finite groups.
3. Demonstrate the knowledge of Rings, ideals of Rings and Quotient rings, Polynomial ring over field and its extension.
4. Learn Fundamental theorem of algebra, Burnside theorem and Kronecker's theorem and solve the problems.
2. Derive and apply Gauss Lemma, and Eisenstein criterion for irreducibility of Polynomials.
3. Demonstrate Field extensions and characterization of finite fields.

**Unit I. Groups, group Homomorphisms (15 lectures)**

Review: Groups, subgroups, normal subgroups, products of subgroups H and K, various cases depending on normality of H and K, center Z(G) of a group. Homomorphisms and kernels. Cyclic groups, Permutation groups, Dihedral groups, Matrix groups, the group of units $U_n$ of $\mathbb{Z}_n$, Lagrange's theorem. (No questions to be asked).

Quotient groups. First isomorphism theorem and examples: quotients of groups of non-zero complex numbers, $Gl_n(\mathbb{R})$, real numbers by integers. Second and third isomorphism theorems for groups, applications. Automorphisms of a group. Automorphisms of cyclic groups. Inner automorphisms of a group. Product of groups. $\mathbb{Z}_{mn}$ as a product, Structure theorem of abelian groups and applications.

**Unit II. Groups acting on sets, Sylow theorems (15 lectures)**

Center of a group, centralizer or normalizer of an element, conjugacy class C(a) of a in G.

Groups acting on sets, Examples: action of G on itself by conjugation, and by left multiplication on itself, and on the set of the left cosets of a subgroup. Centralizers, Normalizers, Orbits and Stabilizers, Cayley's Theorem, Class equation, Cauchy's theorem, p-groups, Commutativity of groups of order $p^2$, centre of a group of order $p^n$, Sylow's theorems and applications. Groups of order 15, 6. Semi-direct products, groups of order 12. Classification of Groups of small orders. Burnside Counting as an application of group action.

**Unit III. Rings, Fields (15 lectures)**

Review: Rings (with unity), ideals, quotient rings, prime ideals, maximal ideals, ring homomorphisms, characteristic of a ring, isomorphism theorems for rings, relation between ideals in the ring and a quotient ring. Integral domains and their quotient fields. (no questions be asked).

Definition of field, characteristic of a field, subfields and prime subfields. Polynomial rings over a field F, irreducible polynomials over F. Prime, and maximal ideals in F[X], and their generators, unique factorization for polynomials over a field.
Definition of field extension, algebraic elements, minimal polynomial of an algebraic element, extension of a field obtained by adjoining one algebraic element. Kronecker's theorem, an application of Kronecker's theorem: Existence of a splitting field of a polynomial.

**Unit IV. Divisibility in integral domains, finite fields (15 lectures)**
Prime elements, irreducible elements, Unique Factorization Domains, Principle Ideal Domains, Gauss's lemma, $\mathbb{Z}$, F[X] are UFD, irreducibility criterion, Eisenstein's criterion, Euclidean domains. Examples of: domain but not a UFD, UFD but not a PID, PID but not a Euclidean domain.
Finite integral domains are fields, Finite fields, order, existence of polynomials with no roots. Existence of a field of characteristic p with $p^n$ elements for and prime p and positive integer n.

**Recommended Text Books**


1. Michael Artin: Algebra, Prentice-Hall India.
2. David Dummit, Richard Foote: Abstract Algebra, Wiley-India.
3. R.B.J.T. Allenby: Rings, Fields and Groups, An Introduction to Abstract Algebra, Elsevier (Indian edition).
4. J. B. Fraleigh, A first Course in Abstract Algebra, Narosa.
5. G. Santhanam, Algebra, Narosa.


## MAT451 - ALGEBRA II

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative (Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. NOC:Algebra II https://nptel.ac.in/courses/111/106/111106151/
2. Basic Algebraic Geometry https://nptel.ac.in/courses/111/106/111106097/

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 1 | - | - | 3 | 1 | - | - | - | - | - | - | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO2** | 2 | - | 1 | 2 | - | - | - | - | - | - | - | 1 |
| **CO3** | 2 | 1 | 2 | 1 | - | - | - | - | - | - | - | 1 |
| **CO4** | 3 | - | 2 | - | - | - | - | - | - | - | - | 1 |
| **CO5** | 1 | - | 3 | 1 | - | - | - | - | - | - | - | 1 |

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

## MAT452: TOPOLOGY

**Course Outcome of Topology:**
**Students will be able to:**

1. Identify topologies and form a topological space using basis and sub-basis.
2. Define connected space and find its components and path components of a topological space.
3. Study of theorems on connectedness, compactness and completeness.
4. State the first, second countability and separable axioms. List the results based on first and second countability.
5. Apply metric space concept to compactness and completeness.

**Unit I. Topological spaces (15 Lectures)**
Topological spaces, basis, sub-basis, product topology (finite factors only), subspace topology, closure, interior, continuous functions, $T_1$, $T_2$ spaces, quotient topology.

**Unit II. Connected and Compact topological spaces** (15 Lectures)
Connected topological spaces, path-connected topological spaces, continuity and connectedness, Connected components of a topological space, Path components of a topological space.
Compact spaces, limit point compact spaces, continuity and compactness, tube lemma, compactness and product topology (finite factors only), local compactness, one point compactification.

**Unit III. Countability and Separation Axioms (15 Lectures)**
Countability Axioms, Separation Axioms, Separable spaces, Lindeloff spaces, Second countable spaces. A compact $T_2$ space is regular and normal space.

**Unit IV. Complete metric spaces (15 Lectures)**
Complete metric spaces, Completion of a metric space, total boundedness , compactness in Metric spaces, sequentially compact metric spaces, uniform continuity, Lebesgue covering lemma, Arzela-Ascoli theorem.

**Recommended Text Books**

1. James Munkres: Topology, Pearson.
2. George Simmons: Topology and Modern Analysis, Tata Mcgraw-Hill.
3. M.A.Armstrong: Basic Topology, Springer UTM.

4. K.D.Joshi: General Topology.

## MAT452– Topology

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative
(Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://nptel.ac.in/courses/111/106/111106054/#
2. https://nptel.ac.in/courses/111/106/111106053/#

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | - | - | - | - | - | - | - | - | 1 |
| CO2 | 2 | 2 | - | 1 | - | - | - | - | - | - | - | 1 |
| CO3 | 2 | - | - | - | - | - | 1 | 1 | - | - | - | 1 |
| CO4 | 3 | - | 2 | - | - | - | - | - | - | - | - | 1 |
| CO5 | - | - | - | - | - | - | - | - | - | - | - | 1 |

*__In CO-PO Mapping Matrix:__ a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

## MAT453: DIFFERENTIAL EQUATIONS AND INTEGRAL TRANSFORM

**Course Outcome of Differential Equation and Integral Transform**

**Students will be able to:**

1. Apply Picard's method for finding solutions of first order differential equations.

2. Expresses the existence and uniqueness results for an $n^{th}$order linear Ordinary Differential Equations.
3. Apply the method of 'variation of parameters' to find solution of higher order linear differential equations with variable coefficients.
4. Define Fourier series and apply for periodic functions.
5. Construct Fourier analysis of daily life periodic functions.

**Unit I. Picard's Theorem ( 15 Lectures)**

Existence and Uniqueness of solutions to initial value problem of first order ODE- both autonomous, non-autonomous (Picard's Theorem), Approximations, system of first order Picard's scheme of successive linear ODE with constant coefficients and variable coefficients, reduction of an n-th order linear ODE to a system of first order ODE.

**Unit II. Linear Ordinary Differential Equations (15 Lectures)**

Existence and uniqueness results for an **n-th** order linear ODE with constant coefficients and variable coefficients, linear dependence and independence of solutions of a homogeneous n-th order linear ODE, Wronskian matrix, Lagrange's Method (variation of parameters), algebraic properties of the space of solutions of a non-homogeneous n-th order linear ODE.

**Unit III. Series solutions and Sturm Liouville theory (15 Lectures)**

Solutions in the form of power series for second order linear equations of Legendre and Bessel, Legendre polynomials, Bessel functions. Sturm- Liouville Theory: Sturm- Liouville Separation and comparison Theorems, Oscillation properties of solutions.

**Unit IV: Fourier series (15 lectures)**

Eigenvalues and eigenfunctions of Sturm-Liouville Boundary Value Problem, the vibrating string. Orthogonality of eigen functions, Dirichlet's conditions, Fourier series expansion of periodic functions (period 2pi & arbitrary period), Complex form of Fourier series, Half range Fourier series, Nth partial sum of Fourier series, Bessel's inequality, Parseval's identity (over complex field).

**Unit V. Laplace Transform (15 Lectures)**

Definition of Laplace Transform, Laplace transforms of some elementary functions, Properties of Laplace transform, Laplace transform of the derivative of a function, Inverse Laplace Transform, Properties of Inverse Laplace Transform, Inverse Laplace Transform of derivatives, Convolution Theorem, Heaviside expansion theorem, Application of Laplace transform to solutions of ODEs and PDEs.

**Unit VI. Fourier Transform (15 Lectures)**

Fourier Integral theorem, Properties of Fourier Transform, Inverse Fourier Transform, Convolution Theorem, Fourier Transform of the derivatives of functions, Parseval's Identity, Relationship of Fourier and Laplace Transform, Application of Fourier transforms to the solution of initial and boundary value problems.

**Recommended Text Books:**

**1. Units I and II:**

(a) E.A. Coddington, An introduction to Ordinary Differential Equations, Dover Publication INC.
(b) E.A. Coddington, N. Levinson, Theory of Ordinary differential Equations, Tata McGraw-Hill, India.
(c) Hurewicz W., Lectures on ordinary differential equations, M.I.T. Press.

(d) Morris W. Hirsch and Stephen Smale, Differential Equations, Dynamical Systems, Linear Algebra, Elsevier.

**2. Unit III and Unit IV:**

(a) G.F. Simmons, Differential equations with applications and historical notes, McGraw-Hill international edition.

(b) G.F. Simmons, S.G. Krantz, Differential equations, Theory, Technique and Practice,

Walter Rudin series in advanced mathematics, 1st edition.

(c) G. B. Folland, Fourier series and its applications, AMS.

3. Brian Davies, Integral transforms and their Applications, Springer.

4. I. N. Sneddon, Use of Integral Transforms, Tata-McGraw Hill.

5. L. Andrews and B. Shivamogga, Integral Transforms for Engineers, Prentice Hall of India.

## MAT453– Differential equations an Integral Transform

**Course Outcomes:** Upon successful completion of this course, students will be able to:

- **CO1:Know and recall the core knowledge of the syllabus.** (To measure this outcome, questions may be of the type- objective, define, identify, state, match, list, name etc.)
- **CO2:Understand the concept.** (To measure this outcome, questions may be of the type- explain, describe, illustrate, evaluate, give examples, compute etc.)
- **CO3:Analyze the problem and apply the appropriate concept**. ( To measure this outcome, questions will be based on applications of core concepts)
- **CO4:Give reasoning.** (To measure this outcome, questions may be of the type- true/false with justification, theoretical fill in the blanks, theoretical problems, prove implications or corollaries of theorems, etc.)
- **CO5:Apply core concepts to new situations.** (To measure this outcome, some questions will be based on self-study topics and also comprehension of unseen Problems.)

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative (Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://nptel.ac.in/courses/111/108/111108081/ .
2. https://nptel.ac.in/courses/111/106/111106046/
3. https://nptel.ac.in/courses/111/104/111104031/
4. https://nptel.ac.in/courses/111106139

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 2 | - | - | - | 1 | - | - | 1 | - | - | - | 1 |
| CO2 | 2 | - | - | 3 | - | - | 1 | - | - | - | - | 1 |
| CO3 | 2 | - | 1 | 1 | - | - | 2 | - | - | - | - | 1 |
| CO4 | - | - | - | 2 | 1 | - | - | - | - | - | - | 1 |
| CO5 | - | - | 1 | 2 | - | - | - | - | - | - | - | 1 |

*In CO-PO Mapping Matrix: a correlation is established between COs and POs in the scale of 1 to 3, 1 being the slight (low), 2 being moderate (medium), 3 being substantial (high), and '-' indicate there is no correlation in respective CO and PO.

## MAT454A: INTRODUCTION TO R PROGRAMMING-II

**Course Outcomes:**

1. Create different types of data frames in R
2. Handel and analyse various files in R
3. Analyse and visualize statistical functions using R.
4. Apply R programming to machine learning and big data analysis.

**UNIT I: Loading and handling Data in R**

Getting and Setting the Working Directory – getwd(), setwd(), dir() - R-CSV Files - Input as a CSV file, Reading a CSV File, Analyzing the CSV File: summary(), min(), max(), range(), mean(), median(), apply() - Writing into a CSV File – R -Excel File – Reading the Excel file. Descriptive Statistics: Data Range, Frequencies, Mode, Mean and Median: Mean Applying Trim Option, Applying NA Option, Median - Mode - Standard Deviation – Correlation - Spotting Problems in Data with Visualization: visually Checking Distributions for a single Variable - R –Pie Charts: Pie Chart title and Colors – Slice Percentages and Chart Legend, 3D Pie Chart – R Histograms – Density Plot - R – Bar Charts: Bar Chart Labels, Title and Colors.

**UNIT II: Descriptive Statistics**

Data Range, Frequencies, Mode, Mean and Median: Mean Applying Trim Option, Applying NA Option, Median - Mode - Standard Deviation – Correlation - Spotting Problems in Data with Visualization: visually Checking Distributions for a single Variable - R –Pie Charts: Pie Chart title and Colors – Slice Percentages and Chart Legend, 3D Pie Chart – R Histograms – Density Plot - R – Bar Charts: Bar Chart Labels, Title and Colors.

**UNIT III: Machine Learning**

Introduction to Machine Learning in R, Setting up Environment for Machine Learning with R Programming, Supervised and Unsupervised Learning in R Programming, Regression and its Types in R Programming, Classification in R Programming , Naive Bayes Classifier in R Programming , K-NN Classifier in R Programming , Clustering in R Programming , Decision Tree in R Programming., Random Forest Approach in R Programming , Hierarchical Clustering in R Programming , DBScan Clustering in R Programming, Deep Learning in R Programming.

**Unit-IV: Practical (Lab Sessions)**

**REFERENCES:**

1. Sandip Rakshit, R Programming for Beginners, McGraw Hill Education (India), 2017, ISBN : 978-93-5260-455-5.

2. Seema Acharya, Data Analytics using R, McGrawHill Education (India), 2018, ISBN: 978-93-5260-524-8.

3. Andrie de Vries, Joris Meys, R for Dummies A Wiley Brand, 2nd Edition, John Wiley and Sons, Inc, 2015, ISBN: 978-1-119-0558-8.

4. Tutorials Point (I) simply easy learning, Online Tutorial Library (2018), R Programming, Retrieved from https://www.tutorialspoint.com/r/r_tutorial.pdf.

5. https://nptel.ac.in/courses/111/104/111104100/

## MAT454A– INTRODUCTION TO R PROGRAMMING-II

**Course Outcomes:** After successful completion of this course, students will be able to:

**CO-1:** Create different types of data frames in R

**CO-2:** Handel and analyse various files in R

**CO-3:** Analyse and visualize statistical functions using R.

**CO-4:** Apply R programming to machine learning and big data analysis.

**ICT Tools Used:** Videos, PPT, Pen-Tablet

**Students Centric Methods:** Problem Solving and Participative (Experimental, Participative, Problem Solving)

**Links: SWAYAM / MOOCS:**

1. https://nptel.ac.in/courses/111/104/111104100/
2. https://nptel.ac.in/courses/110/105/110105142/
3. https://nptel.ac.in/courses/111/104/111104120/
4. https://nptel.ac.in/courses/111/104/111104146/

### The CO-PO Mapping Matrix

| CO\PO | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO1 | 3 | - | - | 1 | - | 1 | - | | - | - | - | 1 |
| CO2 | 2 | - | - | 1 | - | 2 | - | 1 | - | - | - | 1 |
| CO3 | 2 | 1 | 1 | - | - | - | - | 1 | - | - | - | 1 |
| CO4 | 1 | - | - | 2 | - | - | - | 1 | - | - | - | 1 |

# Scheme of Examination

In each semester, the performance of the learners shall be evaluated into two parts. The learner's performance in each course shall be assessed by Continuous Internal Assessment **(CIE)** with 40 marks and conducting the **Semester End Examinations (SEE)** with 60 marks.

**Continuous Internal Assessment of 40 marks:**

| **Paper Code** | **CIE** | **Unit Tests/Seminar** | **Total** |
|---|---|---|---|
| MAT401 MAT402, MAT403, MAT405 and MAT451, MAT452, MAT453, MAT455 | 20 Marks | 20 Marks | 40 Marks |
| MAT404 and MAT454 (SEC) | Practical based on each unit | | 40 Marks |

**Semester End Examination of 60 marks:**

(i) Duration: - Examination shall be of **Two and Half hours** duration.

(ii) Theory Question Paper Pattern: -

1. There shall be five questions each of 12 marks.
2. On each unit there will be one question and the fifth one will be based on entire syllabus.
3. All questions shall be compulsory with internal choice within each question.
4. Each question may be subdivided into sub-questions a, b, c, d and the allocation of marks depend on the weightage of the topic.
5. Each question will be of 24 marks when marks of all the sub-questions are added (including the options) in that question.

| Questions | | Marks |
|---|---|---|
| Q 1 | Based on Unit I | 12 |
| Q 2 | Based on Unit II | 12 |
| Q 3 | Based on Unit III | 12 |
| Q 4 | Based on Unit IV | 12 |
| Q 5 | Based on All Units (I to IV) | 12 |
| | Total Marks | 60 |